

Benjamin Todd Greenhagen

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EDUCATION

University of California, Los Angeles, CA (2005 – 2009)

Ph.D. in Geology (Planetology) (2009)

- Advisor: Dr. David A. Paige
- Dissertation title: “Thermal Emission Remote Sensing of the Moon: Design and Development of Diviner Lunar Radiometer Compositional Capabilities”

Washington University, Saint Louis, MO (2003 – 2005)

M.S. in Earth and Planetary Science (2005)

- Co-advisors: Dr. Bradley L. Jolliff and Dr. Raymond E. Arvidson
- Thesis title: “Infrared and Raman Spectroscopy of Mg Sulfate and Basalt Mixtures as Martian Regolith Analogues”

University of Minnesota, Minneapolis, MN (1998 – 2003)

B.S. in Geophysics (2003)

B.S. in Geology (2003)

- Minors: Astrophysics and Physics

PROJECTS AND MISSIONS

NASA Lunar Reconnaissance Orbiter, Diviner Lunar Radiometer Experiment

Deputy Principal Investigator (2010 – present)

Compositional Investigation Lead (2009 – present)

Collaborator (2005 – 2009)

NASA Mars Reconnaissance Orbiter, Mars Climate Sounder

Collaborator (2005 – present)

RESEARCH EXPERIENCE

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA (2009 – present)

RESEARCH SCIENTIST, Geophysics and Planetary Geosciences Group

Diviner lunar radiometer Compositional Investigation lead. Diviner observation sequence designer. Diviner flight data validation and analysis. Diviner calibration data analysis. Investigation of lunar surface composition at global and regional scales derived from Diviner data. Comparisons/collaborations with other lunar instruments and datasets. Investigation of the use of Diviner derived technology for other planetary surfaces. Researcher for the Lunar Mapping and Modeling Program (LMMP) resource map development team.

University of California, Los Angeles, CA (2009)

STAFF RESEARCH ASSOCIATE, Dept. of Earth and Space Sciences, under Dr. David A. Paige

Development of data analysis tools for 2009 LRO Diviner lunar radiometer Compositional and Thermophysical Investigations. Diviner operational and science planning including the design of in-flight calibrations (commissioning and mapping orbit phases) and investigation of Diviner’s targeting capabilities and collaborations with other lunar orbiting instruments. Analysis of Diviner pre-flight calibration data.

University of California, Los Angeles, CA (2005 – 2009)

GRADUATE STUDENT RESEARCHER, Dept. of Earth and Space Sciences, under Dr. David A. Paige

Designed and developed the 2009 LRO Diviner lunar radiometer Compositional Investigation including selection of channels' passbands, instrument performance modeling, and pre-flight calibrations. Participated in a wide range of Diviner related science planning and operations activities. Conducted laboratory thermal infrared reflectance and emission experiments on lunar analog minerals. Pursued research on remote sensing of planetary surfaces.

Washington University, Saint Louis, MO (2003 – 2005)

GRADUATE RESEARCH ASSISTANT, Dept. of Earth and Planetary Science, under Dr. Bradley L. Jolliff

Laboratory studies of Mg sulfate and basalt mixtures. Performed temporal experiments to observe sample desiccation and sulfate crust efflorescence. Measured samples using thermal infrared reflectance spectroscopy, Raman spectroscopy, and X-ray diffraction.

Aerospace Corporation, Chantilly, VA and El Segundo, CA (2002 – 2005)

MEMBER OF THE TECHNICAL STAFF, under Dr. Laurel E. Kirkland

Infrared remote sensing of field sites in the Mojave Desert, including Death Valley, Bristol Lake, mines in Arizona and Nevada, and adjacent areas. Planned and implemented field studies using truck mounted thermal infrared emission spectrometers. Analyzed ground-based and airborne remote sensing datasets. Designed and wrote software for rapid analysis of data in the field.

University of Minnesota, Minneapolis, MN (2001 – 2003)

UNDERGRADUATE RESEARCH ASSISTANT, under Dr. David L. Kohlstedt

Designed and wrote image processing software to determining melt content of deforming rock samples.

3M Corporation, St. Paul, MN (1999 – 2001)

LABORATORY ASSISTANT, under Dr. Robert K. Galkiewicz

Physical properties of mechanical fasteners. Prepared and tested fastener samples using tensile and shear strength testers. Wrote software to operate tensile strength tester. Created prototypes and mockups using fasteners.

TEACHING EXPERIENCE

University of California, Los Angeles, CA (2005 – 2006)

GRADUATE TEACHING ASSISTANT, Dept. of Earth and Space Sciences, under Dr. David A. Paige

Developed, wrote, and taught discussion section curriculum and exercises, collaborated on lecture curriculum and exams, met with students upon request, and graded student work

- ESS 10: Exploring Mars, The Red Planet (2 quarters)

University of Minnesota, Minneapolis, MN (2001 – 2003)

UNDERGRADUATE TEACHING ASSISTANT, Dept. of Geology and Geophysics, under Dr. Kent C. Kirkby

Taught discussion section curriculum, met with students upon request, and graded student work

- GEO 1001: The Dynamic Earth (4 semesters)

AWARDS AND FELLOWSHIPS

- NASA Group Achievement Award, LRO Diviner Lunar Radiometer Experiment (2010)
- NASA Group Achievement Award, Lunar Reconnaissance Orbiter (2010)
- NASA Group Achievement Award, MRO Mars Climate Sounder (2009)
- Graduate Research and Teaching Assistantship, UCLA (2005 – 2009)
- Best Presentation Award, ESSSO Research Symposium (2007)
- Graduate Research Assistantship, Washington University (2004 – 2005)
- NASA Space Grant Fellowship, Washington University (2003 – 2004)
- Undergraduate Research Opportunity Program Fellowship, University of Minnesota (2001 – 2003)
- Lunar and Planetary Institute Scholarship, LPI Summer Intern (2002)

- Geology Field Camp Scholarship, University of Minnesota (2001)
- Iron Range Scholarship, University of Minnesota (1998 – 2000)
- 3M Richard G. Drew Recognition of Creativity Award (1998)

RECENT ACTIVITIES

- Deputy Principal Investigator, Diviner Lunar Radiometer Experiment (2010 – present)
- President, GSA Math and Physical Sciences Council, UCLA (2007 – 2008)
- MPSC Representative, Graduate Student Association Forum, UCLA (2006 – 2008)
- MPSC Representative, GSA Appointments Board, UCLA (2006 – 2008)
- Dept. of ESS Representative, Math and Physical Sciences Council, UCLA (2006 – 2008)

PUBLICATIONS

Greenhagen, B.T., P.G. Lucey, M.B. Wyatt T.D. Glotch, C.C. Allen, J.A. Arnold, J.L. Bandfield, N.E. Bowles, K.L. Donaldson Hanna, P.O. Hayne, E. Song, I.R. Thomas, and D.A. Paige (2010) Global silicate mineralogy of the moon from the Diviner lunar radiometer, *Science*, **329**, 1507.

Donaldson Hanna K.L., M.B. Wyatt, I.R. Thomas, N.E. Bowles, **B.T. Greenhagen**, A. Maturilli, J. Helbert, and D.A. Paige (2011), Thermal infrared emissivity measurements under a simulated lunar environment: Application to the Diviner Lunar Radiometer Experiment, *Submitted to JGR*.

Thomas I.R., **B.T. Greenhagen**, N.E. Bowles, K.L. Donaldson Hanna, J. Temple, and S.B. Calcutt (2011), A new experimental setup for performing thermal emission measurements of minerals in a simulated lunar environment, *Submitted to JGR*.

Glotch, T.D., P.G. Lucey, J.L. Bandfield, **B.T. Greenhagen**, I.R. Thomas, R.C. Elphic, N. Bowles, M.B. Wyatt, C.C. Allen, K. Donaldson Hanna, and D.A. Paige (2010), Highly silicic compositions on the Moon, *Science*, **329**, 1510.

Hayne, P.O., **B.T. Greenhagen**, M.C. Foote, M.A. Siegler, A.R. Vasavada, and D.A. Paige (2010), Diviner Lunar Radiometer observations of the LCROSS impact, *Science*, **330**, 477.

Paige, D.A., M.A. Siegler, J.A. Zhang, P.O. Hayne, E.J. Foote, K.A. Bennett, A.R. Vasavada, **B.T. Greenhagen**, J.T. Schofield, D.J. McCleese, M.C. Foote, E.M. De Jong, B.G. Bills, W. Hartford, B.C. Murray, C.C. Allen, K.J. Snook, L.A. Soderblom, S. Calcutt, F.W. Taylor, N.E. Bowles, J.L. Bandfield, R.C. Elphic, R.R. Ghent, T.D. Glotch, M.B. Wyatt, and P.G. Lucey (2010) Diviner Lunar Radiometer observations of cold traps in the Moon's south polar region, *Science*, **330**, 479.

Paige, D.A., M.C. Foote, **B.T. Greenhagen**, J.T. Schofield, S. Calcutt, A.R. Vasavada, D.J. Preston, F.W. Taylor, C.C. Allen, K.J. Snook, B.M. Jakosky, B.C. Murray, L.A. Soderblom, B. Jau, S. Loring, J. Bulharowski, N.E. Bowles, I.R. Thomas, M.T. Sullivan, C. Avis, E.M. De Jong, W. Hartford, and D.J. McCleese (2009), The Lunar Reconnaissance Orbiter Diviner Lunar Radiometer Experiment, *Space Science Reviews*, **150**, 125.

FIRST AUTHOR PRESENTATIONS

Greenhagen, B.T., I.R. Thomas, N.E. Bowles, C.C. Allen, K.L. Donaldson Hanna, E.J. Foote, and D.A. Paige (2011), Comparison of Diviner Lunar Radiometer observations of Apollo sites and Apollo soils measured in simulated lunar environment, 2011 Goldschmidt Meeting, Prague, CZ.

Greenhagen, B.T., D.A. Paige, and the Diviner Science Team (2011), Thermal properties of the Moon observed by the Diviner instrument on LRO, 2011 NASA Lunar Science Forum, Moffett Field, CA.

Greenhagen, B.T., N.E. Petro, K.L. Donaldson Hanna, P.G. Lucey, and D.A. Paige (2011), Diviner observations of lunar farside compositional anomalies, 2011 NASA Lunar Science Forum, Moffett Field, CA.

Greenhagen, B.T., P.G. Lucey, J.L. Bandfield, P.O. Hayne, J.P. Williams, and D.A. Paige (2011), The Diviner Lunar Radiometer compositional data products: description and examples, 42nd Lunar and Planetary Science Conference, Houston, TX.

Greenhagen, B.T., N.E. Petro, P.G. Lucey, M.B. Wyatt, K.L. Donaldson Hanna, C.M. Pieters, T.D. Glotch, J. Arnold, C. Allen, N.E. Bowles, I.R. Thomas, and D.A. Paige (2010), Silicate mineralogy of SPA: A new view from the Diviner Lunar Radiometer, AGU Fall Meeting, San Francisco, CA.

Greenhagen, B., P. Lucey, M. Wyatt, T. Glotch, C. Allen, J. Arnold, J. Bandfield, N. Bowles, K. Donaldson Hanna, P. Hayne, I. Thomas, and D. Paige (2010), The LRO Diviner Lunar Radiometer Compositional Investigation after one year of mapping, Division for Planetary Sciences 42nd Annual Meeting, Pasadena, CA.

Greenhagen, B.T., P.G. Lucey, M.B. Wyatt T.D. Glotch, C.C. Allen, J.A. Arnold, J.L. Bandfield, N.E. Bowles, K.L. Donaldson Hanna, P.O. Hayne, E. Song, I.R. Thomas, and D.A. Paige (2010), Lunar compositional diversity as observed by the LRO Diviner lunar radiometer, 2010 NASA Lunar Science Forum, Moffett Field, CA.

Greenhagen, B.T., D.A. Paige, P.O. Hayne, A.R. Vasavada, and P.G. Lucey (2010), Lunar surface albedo as observed by the Diviner lunar radiometer, 2010 NASA Lunar Science Forum, Moffett Field, CA.

Greenhagen, B.T., P.G. Lucey, T.D. Glotch, J.L. Bandfield, C.C. Allen, N.E. Bowles, I.R. Thomas, M.B. Wyatt, K.L. Donaldson Hanna, and D.A. Paige (2010), Global distribution of lunar silicates from the Diviner lunar radiometer, 41st Lunar and Planetary Science Conference, Houston, TX.

Greenhagen, B.T. D.A. Paige, P.G. Lucey, C.C. Allen, J.L. Bandfield, N.E. Bowles, K.L. Donaldson Hanna, T.D. Glotch, I.R. Thomas, and M.B. Wyatt (2009), LRO Diviner lunar radiometer: Compositional investigation coverage and early results, AGU Fall Meeting, San Francisco, CA.

Greenhagen, B., D. Paige, C. Allen, J. Bandfield, N. Bowles, K. Donaldson Hanna, T. Glotch, P. Hayne, P. Lucey, I. Thomas, and M. Wyatt (2009), Early results from the Diviner lunar radiometer compositional investigation, Division for Planetary Sciences 41st Annual Meeting, Fajardo, PR.

Greenhagen, B.T., D.A. Paige, M.C. Foote, F.E. Leader, and J.T. Schofield (2009), LRO Diviner Lunar Radiometer Commissioning Phase Activities, 2009 NASA Lunar Science Forum, Moffett Field, CA.

Greenhagen, B.T. and D.A. Paige (2009), Overview of the 2009 LRO Diviner lunar radiometer compositional investigation, 40th Lunar and Planetary Science Conference, Houston, TX.

Greenhagen, B.T. and D.A. Paige (2008), Laboratory visible to far-infrared measurements in support of the 2009 LRO Diviner lunar radiometer compositional investigation, AGU Fall Meeting, San Francisco, CA.

Greenhagen, B.T. and D.A. Paige (2007), Thermal effects of lunar surface roughness: Application for the 2008 LRO Diviner Lunar Radiometer Experiment, American Geophysical Union Fall Meeting, San Francisco, CA.

Greenhagen, B.T. and D.A. Paige (2006), Mapping lunar surface petrology using the mid-infrared emissivity maximum with the LRO Diviner radiometer, 37th Lunar and Planetary Science Conference, Houston, TX.

Greenhagen, B.T., L.E. Kirkland, P.M. Adams, and T.K. Grabowski (2005), MarsLab investigation of the spectral signature of gypsum bearing rocks of differing composition and formation environment, 36th Lunar and Planetary Science Conference, Houston, TX.

Greenhagen, B.T., L.E. Kirkland, T.K. Grabowski, and E.S.G. Rainey (2004), A tool for the 2003 rover Mini-TES: Downwelling radiance compensation using integrated line-sight sky measurements, 35th Lunar and Planetary Science Conference, Houston, TX.

Greenhagen, B.T., L.E. Kirkland, and K.C. Herr (2003), Mars analogue field spectroscopy: Building real-world experience for the Mars 2003 rover Mini-TES, 34th Lunar and Planetary Science Conference, Houston, TX.

Greenhagen, B.T., L.E. Kirkland, and K.C. Herr (2002), Terrestrial analogue field thermal emission spectroscopy: Applications to the MER Mini-TES, Fall Meeting, San Francisco, CA.